Recent Research Developments Affecting Non-Life Insurance—The CAS Risk Premium Project 2015 Update

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Abstract

This paper reports the 2015 update results of the CAS Risk Premium Project, a review of the research developments in 2015 that affect the non-life risk assessment. We highlight the topics of reinsurance and behavioral insurance. Discussing the potential systemic relevance of reinsurers, scholars try to improve the efficiency of the reinsurance market and the design of reinsurance contracts. Along with the classical insurance theories based on expected utility and risk averse, practices deviating from the classical prediction motivate scholars to apply behavioral methodologies. They investigate how people perceive risks differently from how risks actually are and how insurance demand changes correspondingly. The behavioral results provide additional insights to the non-life insurance management.

Keywords

Property-casualty insurance, Reinsurance, Behavioral insurance, Cyber risk, Risk control

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Background

This paper presents the main results of the fifth annual update of the Casualty Actuarial Society (CAS) Risk Premium Project (RPP), and its corresponding Risk Assessment Database (RAD). RPP and RAD aim to provide structured summaries of and continuous updates on new theoretical and empirical developments in the field of non-life risk assessment. The RPP I Report (Cummins, Phillips, Butsic, and Derrig, 2000) was published in 2000 focusing on the actuarial and finance literature between 1990 and 1999; the RPP II Report (Eling and Schmeiser, 2010) was published in 2010 with a review of actuarial science, risk management, and insurance literature between 2000 and 2010.

After that, the CAS Committee on the Theory of Risk (COTOR) decided to conduct RPP/RAD annual updates, considering the attention and frequent visits to the RAD database (http://www.casact.org/research/rad). The previous four annual updates summarize the research developments affecting non-life insurance during 2011-2014. The results of these updates were discussed in four update reports, respectively (Eling, 2013; Biener and Eling, 2013; Biener, Eling, and Pradhan, 2015; Eling and Jia, 2016). The RPP/RAD annual updates involve two major steps: (1) an update of the RPP/RAD bibliography database (http://www.casact.org/research/rad); and (2) the report that structuralizes and synthesizes new knowledge and techniques, thus highlighting important developments in the non-life risk assessment. The thematic structure of the annual updates was developed in the RPP II Report (Eling and Schmeiser, 2010), which incorporates opinions from both a broad range of academics and COTOR.

The RPP/RAD 2015 update was conducted during December 2015 and March 2016. In total, 99 new qualified papers were added to the RPP literature database that were identified using a thorough literature search conducted by researchers at the University of St. Gallen, along with papers and research reports recommended by CAS and COTOR members. The literature review was based on the literature search strategy and results-evaluation process used in RPP II (see Eling and Schmeiser, 2010, for the details of the review process). Comments from CAS and COTOR members were received via email and via the online feedback template on http://www.casact.org/research/rad, which were integrated in this update.

In the following section, we present the main results and highlight the most important developments from the 2015 update for each thematic category. We focus on research published in academic journals in the fields of actuarial science, risk management, and insurance, but also consider related fields, e.g. finance and economics. Conclusions and

initiatives implemented in this update are provided at the end.

Results

The literature review is based on the thematic classifications in RPP II (Eling and Schmeiser, 2010) (see also http://www.casact.org/research/rad). Following the risk assessment process, three top-level categories are identified as risk identification, risk valuation, and risk management. These top-level categories are then further subdivided into 11 sub-categories. Table 1 provides an overview of the papers updated for each thematic categories in all updates since RPP II. Papers may cover several elements of the risk assessment process and thus qualify for more than one category. In such case, we allocate the paper exclusively into its closest thematic category.

Table 1

Thematic categories and number of papers added in each update

Thematic category	Number of papers added					
	2015 update	2014 update	2013 update	2012 update	2011 update	2010 RPP II
Panel A: Risk identification	27	32	23	15	14	225
Operational risk	5	6	6	3	4	31
Catastrophe risk	6	6	13	5	3	102
Other emerging risks (e.g., systemic risk)	16	20	4	7	7	92
Panel B: Risk valuation	41	37	66	62	37	547
CAPM/asset pricing	5	4	6	12	6	134
Insurance risk	16	14	27	25	16	44
New valuation techniques	1	6	19	9	6	114
New risk measures (e.g., tail value at risk)	9	6	9	12	7	217
Behavioral insurance	10	7	5	4	2	38
Panel C: Risk management	31	31	16	18	17	178
Surplus/capital allocation	3	5	5	6	4	71
Risk control	7	2	4	2	7	60
Reinsurance and alternative risk transfer	21	24	7	10	6	47
Total	99	100	105	95	68	950

Overall, 99 new papers were added during the 2015 update with the risk valuation category receiving the most (41 new papers), followed by risk management category (31 new papers) and the risk identification category (27 new papers). The papers added in this update are relatively evenly distributed among the three top-level thematic categories. The source journals under each of the three top-level topic categories are summarized in Appendix 1. We acknowledge that certain subjectivity is unavoidable although we tried to be as objective as possible when selecting publications and we took recommendations from colleagues and CAS

members. Further recommendations for additions to the list are welcome and can be made on http://www.casact.org/research/rad.

Risk identification

A sound risk management process usually starts with the identification of different kinds of risks. Following RPP II, we focus on three types of risks that are operational risk, catastrophe risk, and other emerging risks. We add a sub-category of cyber risk to the emerging risk class, in order to reflect its increasing importance in the insurance community.

Operational risk. Due to the "low frequency, high severity" characteristic of operational risk, the extreme value theory (EVT) is particularly useful. Chavez-Demoulin, Embrechts, and Hofert (2015) extend the application of EVT. They let the parameters of the frequency and severity distribution depend on covariates and time. This approach increases the flexibility and accuracy of operational risk models. Other researchers concentrate on the characteristics of specific types of operational risk. For example, Boyer and Tennyson (2015) study empirically the market for Directors' and Officers' insurance (DOI). They prove the existence of moral hazard in the DOI market because DOI promotes the risk taking of the company's management. However, they do not find evidence to support DOI's hypothesized function of governing the company's board.

Catastrophe risk. Kunreuther (2015) discusses the challenges in natural disaster insurance. He points out that due to the "low frequency and high severity" characteristic, the market participants have limited experience and thus are short term orientated, intuitive (irrational), and heuristic. As a result, the society's protection level against cat risks is suboptimal. Kunreuther (2015) proposes a solution as the public-private-partnership. The government should take measures to encourage investment in self-protection, improve affordability of insurance, and provide government-backed coverage for risks that the private market has insufficient appetite or capacity. Dumm, Johnson, and Watson (2015) discuss another scheme to enhance the insurability of cat risks. They conclude that larger and more geographically diversified cat risk pools can lower the uncertainty and thus the required reserves for insuring natural catastrophes.

In an event study, Yamasaki (2015) analyzes the stock price behavior of Japanese property and liability insurers in the period of typhoon landfalls. He shows that the cumulative abnormal returns are positive when the disaster is taking place. Thus, he concludes that the investors evaluate the gains from an increase in the insurance demand induced by such

disasters are higher than the indemnities the insurer potentially has to pay (i.e. “gain from loss”).

Other emerging risk. After the 2008 financial crisis, many studies have been concentrated on systemic risk. A special issue *Insurance and Finance* where several contributions discuss financial stability and related systemic risks have been published by *Geneva Papers on Risk and Insurance-Issues and Practice*. The leading article was contributed by Thimann (2015). He discusses the different roles that insurance companies and banks play in contributing to systemic risk. He points out that insurers do not share the problematic features with banks such as the interconnectedness through the interbank market, the maturity transformation, the high leverage, and the risk of bank runs. Due to these features of insurance companies, Thimann (2015) argues that instead of focusing on minimum capital requirements, the regulators should for example ban certain products (e.g. CDS), set investment limits (e.g. bank bonds), and regulate the policy design (e.g. restricting laps option). Bierth, Irresberger, and Weiß (2015) provide empirical evidence on insurers’ contribution to the systemic risk. Their analyses suggest that for the non-crisis period, the insurance industry suffers from systemic risk rather than being the source of it. However, during the financial crisis, the industry becomes a contributor to the systemic risk.

Microinsurance is another frequently discussed emerging risk topic. In a literature review, Cole (2015) comes to the conclusion that risk management tools can promote income and welfare of the poor. The author predicts faster growth of microinsurance in the future due to new technologies and rising income levels. Moreover, Cole (2015) advocates that the governments should help the development of microinsurance by providing the required infrastructure, educating financial decision-making, supporting microinsurers, and ensuring consumers’ protection. Cai, Chen, Fang, and Zhou (2015) provide empirical evidence for the effect of microinsurance on the economic development. They show that promoting agricultural insurance to Chinese farmers increases the sow production.

Cyber risk has become an eye-catching topic in 2015. The businesses expect their insurance providers to help them manage their cyber risk and the insurance industry calls for research inputs to better understand the risk nature, pricing, and effective product design of cyber risk insurance. Biener, Eling, and Wirfs (2015) comprehensively investigate the characteristics of cyber risk and explain from the insurability perspective why the cyber risk insurance market remains underdeveloped. They document the detrimental factors as information asymmetries, the lack of data, poor methods for premium and reserve calculation, limited diversification

potential caused by correlations and small portfolios, and heavy tail distributions. They also suggest some remedies for the market failure such as insurance pools and government interventions. Zelle and Whitehead (2014) discuss cyber risk from a regulatory point of view. They expect the cyber risk insurance market to expand, call for new regulation initiatives, and recommend that regulators should improve their understanding of cyber risk.

Risk valuation

The category of risk valuation comprises papers describing, pricing, and evaluating the identified risks. We focus on four sub-categories that are CAPM/asset pricing, insurance risk, new valuation techniques (introduced by new regulatory requirements), new risk measures, and behavioral insurance.

CAPM/asset pricing. Several papers discuss how new regulations can influence an insurer's asset allocation decision. The limited liability of shareholders can cause insurers to shift risk to policyholders by increasing its asset and liabilities risks. Filipović, Kremslehner, and Muermann (2015) show in their model that capital requirements indeed reduce risk shifting and encourage a less risky asset allocation. They also provide empirical evidence for non-life insurers that the Solvency II capital requirement reduces risk shifting from shareholders to policyholders. They conclude that other requirements, such as investment restrictions, policies with participation, and mutual organization type would have similar impact on the risk shifting. In comparison, Braun, Schmeiser, and Schreiber (2015) conduct an optimization for insurers' assets portfolios under the constraints imposed by Solvency II. Since the standard formula for the market risk is not sensitive to expected returns and diversification effects, the return-volatility-efficient asset allocation is distorted. They conclude that current Solvency II capital requirements reduce the policyholders' protection as well as the shareholders' value. Fischer and Schlütter (2015) investigate how the Solvency II capital requirement for market risk influences the insurers' asset allocation and capital decisions. They argue that a higher capital charge should intuitively reduce both the investments in risky asset and the company's default probability. However, they show that while the insurance would indeed reduce its risky investments, the default probability does not decrease. This is due to the fact that an insurer aiming at maximizing shareholder value would simultaneously reduce its equity capital.

A growing and lucrative investment opportunity for insurers is the contingent convertible (CoCo) bond issued by banks. In the case of a bank's default, CoCo bonds are turned into shares of the bank. However, the current Solvency II market risk formula does not take the

conversion possibility adequately into account and tends to underestimate CoCo bonds' risk. Niedrig and Gründl (2015) also show that the Solvency II model sets irrational incentive for insurers to excessively invest in CoCo bonds.

Insurance risk. A major part of insurance risk valuation focuses on modelling the loss distribution. In order to account adequately for the heavy tails of insurance underwriting risks, the loss model usually use a weighted composition of a body (losses below a certain threshold) and a tail distribution (above the threshold). It is standard that the body is modeled as a lognormal or Weibull distribution and the tail is described by a Pareto distribution (Bakar, Hamzah, Maghsoudi, and Nadarajah, 2015). Bakar et al. (2015) generalize the above standard approach by replacing the tail's Pareto distribution with the transformed beta distribution family. They find that their new composite models perform better than the standard models, especially when the tails are assumed to be Burr, Inverse Para-, or Log-logistic distributed. This approach is better than the standard models using Lognormal, Gamma, and Pareto distributions, particularly when modelling highly skewed loss data.

The aggregated loss distribution is frequently modeled as the composition of a loss severity distribution and a loss frequency distribution (i.e. number of losses in a certain period). For the sake of simplicity, it is usually assumed that the loss severity and frequency distributions are independent. However, Hua (2015) uses the data on medical expenditures and shows that the dependency between the frequency and severity gets increasingly negative further out in the upper tails. Hua (2015) derives the conditions required for copulas to capture the negative upper tail dependency.

Li, Ni, and Constantinescu (2015) concentrate on the pricing of insurance risks. They suggest a model where the premium is periodically adjusted according to the claim history (emulating a bonus-malus-system) and unforeseeable risks (lack of historical data). Their scheme has the advantage that clients' premiums are calculated more fairly according their risk profiles.

Zavadil (2015) looks at the Dutch car insurance market and examines whether a higher coverage indeed causes more frequent and severe damage as predicted by theory. Even after controlling for the insureds' experience rating, the author does not find any evidence for the existence of asymmetric information. On the contrary, Aarbu (2015) demonstrates that in the home insurance market robust evidence for asymmetric information exists. Additional tests suggest that it might be attributed to adverse selection.

New valuation techniques. This subtopic received less attention comparing to previous years. Gan and Lin (2015) develop a novel functional data approach to valuate large variable annuity

portfolios, which significantly improves the efficiency and reduces the calculation burden of nested simulation approach. Variable annuity is the new type of annuity that policyholders and insurers share the investment risk. The authors demonstrate the accuracy and efficiency of the new functional data approach in a large simulated variable annuity portfolio.

New risk measures. Several studies investigate possible extensions, properties, and applications of the Value-at-Risk (VaR). In situations when risks need to be aggregated, such as solvency calculations, Bernard, Rüschendorf, and Vanduffel (2015) argue that usually only the portfolio's variance and its components' marginal distributions are known. Thus, they derive bounds for a portfolio's VaR when only limited information is available. Bernard et al. (2015) conclude that the portfolio's variance is especially useful for deriving efficient bounds since it contains information about the constituents' correlation.

While the classic VaR is defined for univariate risks, Torres, Lillo, and Laniado (2015) propose an extension to the multivariate setting where a portfolio of heterogeneous and dependent risks is analyzed. Their VaR is evaluated in a certain direction that can represents external information, such as the manager's preferences or the portfolio weights. In the case of portfolio weights, their VaR provides an upper bound for the portfolio's overall (univariate) VaR. Similarly, Di Bernardino, Fernández-Ponce, Palacios-Rodríguez, and Rodríguez-Griñolo (2015) extend the univariate conditional VaR to a multivariate setting and analyze its properties for different dependency structures. Moreover, they estimate the new risk measure with insurance data.

Due to the shortcomings of VaR, such as non-coherence and insensitivity to extreme values, scholars explore alternative risk measures with better properties. Ignatieva and Landsman (2015) discuss the tail conditional expectation (TCE) and tail variance premium (TVP). While the TCE is a coherent risk measure, the TVP is the most conservative measure because it accounts for the variation in the tails. They prove that TCE and TVP for a portfolio's components can easily be aggregated to the portfolio's overall risk measure. Due to the desirable properties, these risk measures could be used to calculate an insurer's solvency capital.

Behavioral insurance. The studies in behavioral insurance aim at explaining why observed market behavior deviates from that predicted by neoclassical theory. Behavioral insurance has attracted an increasing amount of academic attention. Jaspersen and Aseervatham (2015) investigate how affects (emotion) influence the insurance demand. They conduct an experiment and show that emotional activation can cause heuristic (affective) decision

making. Instead of being rational, an insurer's marketing strategy and its advertising message should capture and meet the customer's emotion, if potential customers are in an emotional activated state. In contrast, a rational marketing argument would be more convincing for clients who are not in an affectively activated setting. Browne, Knoller, and Richter (2015) also focus on the topic of insurance demand from a behavioral point of view. They find that customers tend to have a higher demand for protection against high probability and low severity risks (such as bicycle theft) than for low probability, high consequence risk (such as flooding).

Cole, Fier, Carson, and Andrews (2015) investigate whether changing the insurance company's name affects the premium volume (instead of the stock price as it has conventionally been done). They find that changing the name causes a significant and robust increase in subsequent premium volume. They conclude that the market commonly views a name change as a positive sign and it can therefore be a value-enhancing strategy.

Risk management

In the following, we discuss three subcategories of risk management that are capital allocation, risk control, and reinsurance (including alternative risk transfer).

Capital allocation. Targino, Peters, and Shevchenko (2015) investigate the capital allocation issue for dependent risk in a portfolio. They propose a new Sequential Monte Carlo (SMC) sampler algorithm that is more efficient and that can correct the inaccuracy of capital allocation resulted from the rare events. However, the authors also point out the slower SMC algorithm comparing to the conventional Monte Carlo in certain circumstances.

Risk control. Two papers in the *Journal of Risk and Insurance* investigate whether a mature and well developed enterprise risk management framework has a positive effect on a company's performance. Farrell and Gallagher (2015) find that the firm's value as measured by the Tobin's Q increases with maturing management. They argue that the management's commitment and the risk management culture improves with increasing risk management maturity. More specifically, Grace, Leverty, Phillips, and Shimpi (2015) find that the use of economic capital models, dedicated risk managers, and risk management reports improve the operating performance.

In the 2015 update, we group all the asymmetric information works and reallocate them under the category of risk control. This change reflects the focus-shift trend of asymmetric information studies from the identification (existence) of adverse selection or moral hazard to the risk management measures to mitigate the negative impact of asymmetric information,

i.e., the management of asymmetric information. Group insurance might be a means for mitigating adverse selection. However, Eling, Jia, and Yao (2015) demonstrate that the group insurance schemes are not sufficient to eliminate adverse selection. Their result suggests that the insurer's learning over time about the insureds' risk type is important to address adverse selection.

Reinsurance and alternative risk transfer (ART). Similar to last year, 24 additional papers confirm that his subcategory receives a lot of attention. After the financial crisis, the academia becomes aware of the systemic relevance of reinsurers and their important role in stabilizing the economy. We discuss four topics that are reinsurance market structure, reinsurance demand, asymmetric information, and alternative risk transfer.

Boyer and Dupont-Courtade (2015) present the actual structure of the global reinsurance market using actual quotes. They show several interesting facts. Firstly, the number of reinsurance layers and market participants are increasing, resulting in additional complexity in the reinsurance market. Moreover, the characteristics of layers (e.g., limits) influence the reinsurers' quotes positively; while the priority and seniority has a negative impact on the prices. Finally, quotes are also influenced by the lines of business and market structure (number of bids, presence of brokers).

Lin, Yu, and Peterson (2015) build a model that describes the primary insurers' demand for reinsurance. According to the pecking order theory, it can be costly to raise external capital to finance newly written business. Alternatively, reinsurance can also help to finance the primary insurers. Whether the reinsurance solution is superior to external financing is a question of the reinsurance costs. Lin et al. (2015) suggest that the primary insurer's network of reinsurers (i.e. reinsurers that the primary insurer used to work with) is an important determinant of the reinsurance costs and thus of the reinsurance demand. Their model features two network characteristics that are centrality (number of reinsurers) and cohesion (how close the correlation among reinsurers). Since each characteristic affects two different costs components in opposite directions, Figure 1 shows that the optimal reinsurance demand is inverted U-shaped. Their model is supported by non-life insurance data worldwide.

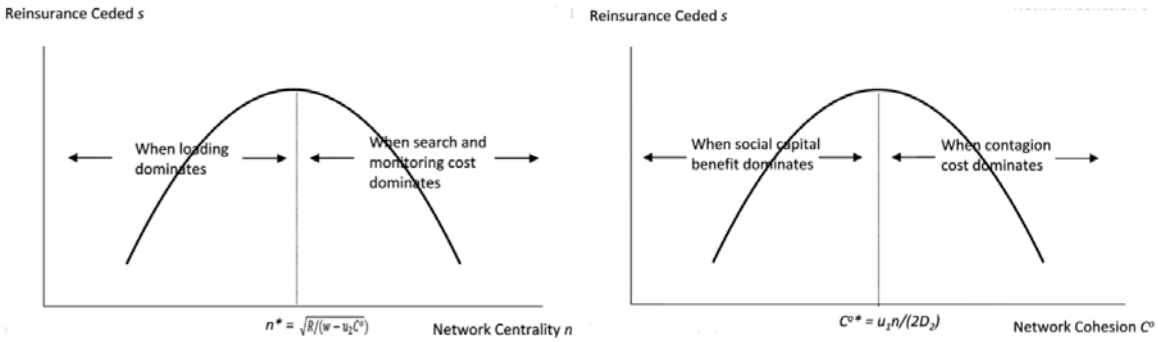

Figure 1 Effects of network centrality and cohesion on reinsurance demand (Lin et al., 2015)

Yan and Hong (2015) investigate the existence of asymmetric information in the reinsurance market by analyzing the correlation between coverages and ex-post risks. They find evidence of asymmetric information in the reinsurance markets for car and home owners but not for product liability. Moreover, they discover that in the reinsurance market, coverage limits are widely used to mitigate asymmetric information but long-term contracting is not.

CAT bonds are one of the most broadly used alternative risk transfer (ART) instrument and its volume has been steadily rising. Carayannopoulos and Perez (2015) study the risk and diversification properties of CAT bonds. While in non-crisis periods, CAT bonds are indeed a zero-beta investment, but become correlated with the market in the financial crises. However, systematic risk in the financial crisis is lower for CAT bonds than many other assets, and thus they are a valuable source of diversification.

Braun (2015) investigates the pricing practice at issuance of CAT bonds. At first, he empirically identifies the factors that drive the CAT bond spreads (insurance premium consisting of expected loss plus a risk premium) such as the expected losses, the covered territory, the sponsor (insurer), the reinsurance cycle, and the corporate bond spreads. Based on these findings, Braun (2015) develops an econometric pricing model that shows better performance than models introduced by earlier works. Since this model only focuses on the pricing of newly issued bonds, the author suggests that future research should be aimed at developing similar models for the consecutive valuation in the secondary market.

Weather derivatives that are based on some kind of weather indices (e.g. temperature, rainfall), can also serve as ART. Since the classical assumptions (e.g. continuously trading of the underlying) are not satisfied, the pricing of such derivatives can be quite challenging. However, Härdle, López-Cabrera, and Teng (2015) estimate the state price density (SPD) that is used for the risk-neutral pricing. They argue that their new estimation method of the SPD

overcomes the difficulties encountered in weather derivative markets (e.g. incomplete market).

Conclusions

The RPP/RAD 2015 update discusses the new research developments affecting non-life insurance in 2015. We continuously optimize the update process with two initiatives implemented in this 2015 update. (1) We create a new topic sub-category under the emerging risk that is the cyber risk, which has been an important topic in the past decade in computer science research. Until recently, the risk management techniques and insurance solutions become prevalent in discussion on assessing cyber risk. (2) To minimize the subjectivity in the paper selection, we consult more researchers with actuarial science background and follow the advice of the last-year referees to balance the weight of actuarial science works and risk management and insurance works.

The RPP/RAD 2015 update covers a broad range of topics following the process of risk assessment, including risk identification, risk valuation, and risk management. We highlight two important topics that capture the research attention: reinsurance and behavioral insurance. The reinsurance becomes increasingly important after the financial crisis, during which the scholars recognize its systemic relevance and pay more attentions to its market efficiency and structure and to its optimal contract design. The behavioral insurance studies explain why the observed market behavior deviates from that predicted by neoclassical theory. This stream of studies emerges quickly and often involves psychology techniques and experiments.

Following the path of the above topics, many questions about insurance companies' risk management remain unanswered and deserve further attention. One of them is the cyber risk, which remain a relatively green field in the risk management and insurance research. The businesses expect their insurance providers help them with the cyber risk and the insurance industry calls for research inputs to better understand the risk nature, pricing, and effective product design of cyber risk insurance. The major challenges in cyber risk research are the data quality and availability. Another prospect trend in the insurance research is the shift of asymmetric information studies from the identification (the existence of adverse selection or moral hazard) to the risk management measures to mitigate (eliminate) the negative impact of asymmetric information. Future research may help to answer whether the asymmetric information persists in a multi-period contracting framework. If yes, what could be done to mitigate it; and if no, what are the effective measures.

Appendix 1 Source journals by topic categories

Panel A: Risk identification	
Journal of Risk and Insurance	8
Geneva Papers on Risk and Insurance-Issues and Practice	8
Journal of Operational Risk	3
American Economic Review	2
Insurance: Mathematics and Economics	1
Journal of Banking and Finance	1
Journal of Insurance Regulation	1
Journal of Risk and Uncertainty	1
Quinnipiac Law Review	1
Review of Economics and Statistics	1
Subtotal	27
Panel B: Risk valuation	
Insurance: Mathematics and Economics	15
Journal of Risk and Insurance	9
Journal of Risk and Uncertainty	6
ASTIN Bulletin	4
American Economic Review	2
Geneva Papers on Risk and Insurance-Issues and Practice	2
Journal of Banking and Finance	1
Review of Economics and Statistics	1
Geneva Risk and Insurance Review	1
Subtotal	41
Panel C: Risk management	
Insurance: Mathematics and Economics	14
Journal of Risk and Insurance	10
Geneva Papers on Risk and Insurance-Issues and Practice	4
ASTIN Bulletin	1
Journal of Banking and Finance	1
Journal of Operational Risk	1
Subtotal	31
Grand total	99

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